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ABSTRACT

This study is an investigation of 2-month-old infants' abilities to visually localize visual and auditory peripheral stimuli. Each subject (N=40) was presented with 50 trials; 25 of these visual and 25 auditory. The infant was placed in a semi-upright infant seat positioned 122 cm from the center speaker of an arc formed by five loudspeakers. At each speaker location there was also a low-intensity light source. Each trial was initiated with the center light on. Via an infra-red camera aimed at the infant's face, an experimenter in the control room could determine whether the infant was fixating this light, and when the baby was doing so, the trial proper was begun. The center light was then replaced for 5 seconds by a similar light at one of the five positions on visual trials and by a sound at one of the five positions on auditory trials. The visual and auditory trials were randomly interspersed, and the order of stimulus positions was also randomly determined. Also recorded were the infant's eye movements using electro-oculography. Results indicate that infants are able to visually localize visual and auditory stimuli. However, these two localization responses are quite different from one another. While infants turn their eyes toward peripheral visual stimuli with the consistency and precision characteristic of reflex behavior, they turn their eyes toward peripheral auditory stimuli with considerably less consistency and with no precision at all. (Author/MP)

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Infants' visual localization of visual and auditory targets

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I'd like to preface my presentation by saying that the research I'm going to describe was initiated primarily by a fellow graduate student at the University of Minnesota, Gordon Bechtold, who became ill and died in 1977. Gordon designed the study, and collected and scored the data. Though we certainly feel the study is an important one with important results, it is also as an acknowledgement of Gordon's efforts and interest in the area that Phil Salapatek and I completed the research, analyzing and interpreting the data.

The study is an investigation of infants' abilities to visually localize visual and auditory peripheral stimuli. Organisms of many species turn their eyes toward the direction from which a sound is coming, just as they turn their eyes toward the locus of visual stimulation. In both cases the localizing behavior serves a useful purpose; namely, to more precisely identify the source of stimulation so that an appropriate response can be made.

The abilities of human infants to localize visual stimuli are well documented. For example, Aslin and Salapatek (1975) reported that not only did 1- and 2-month-old babies move their eyes appropriately towards a peripherally introduced visual stimulus, but the size, latency and liklihood of multiple saccades for such localizing movements were directly related to the eccentricity of the stimulus. Infants' abilities to visually localize auditory stimuli are less certain, however. The conclusions drawn from research investigating this issue range from the

suggestion that infants turn away from sounds (Butterworth & Castillo, 1976) to that they turn toward sounds (Wertheimer, 1961; Turkewitz, Birch, & Cooper, 1972) to that their visual behavior is unaffected by the locations of sounds (McGurk, Turnure, & Creighton, 1977). Differences in parameters such as the intensity and quality of the sound stimulation, the duration of the sound stimulation, and the specific age and state of the subjects are deemed responsible for these conflicting findings. In our study, the abilities of 2-month-old infants to visually localize visual and auditory targets were assessed using identical procedures and a within-subjects design, in an effort to define the relative natures of these two perceptual-motor behaviors. To foretell our results briefly, we found that infants were able to visually localize both visual and auditory targets, but that these two localization responses were quite different from one another in some important ways.

The subjects were normal, healthy babies within a week of their 2nd-month birthdays. Each subject was to be presented 50 trials, 25 of these visual and 25 auditory. The infant was placed in a semi-upright infant seat positioned 122 cm from the center speaker of an arc formed by five loudspeakers, as is depicted in Figure 1. In addition to the speaker at midline, there were also speakers located 20° to the infant's left and right and 10° to the left and right. At each speaker location there was also a low-intensity light source. Except when one of these small lamps was on, the experimental chamber was completely dark. Each trial was initiated with the center light on. Via an infra-red video camera aimed at the infant's face, an experimenter in the control room could determine whether the infant was fixating this light, and when

the baby was doing so, the trial proper was begun. The center light was then replaced for 5 seconds by a similar light at one of the five positions on visual trials and by a sound at one of the five positions on auditory trials. The sound stimulus was a train of 50 msec bursts of white noise occurring 10 times per second. Over the course of data collection, the intensity of the sound stimulus ranged from 53 to 63 dB, as background noise conditions kept changing. The visual and auditory trials were randomly interspersed, and the order of stimulus positions was also randomly determined.

Eye movements were recorded by electro-oculography (EOG). Recording electrodes were placed at the external canthus of each eye and at the center of the forehead for grounding. Only the data from infants who provided scorable EOG records for at least three trials at each of the four lateral positions for both visual and auditory stimuli were included in our analyses. This criterion left us with 40 infants observed exactly as I've described to you. There were also 10 other infants providing sufficient data who were positioned closer to the central speaker, so that the targets were located 20° and 40° to the left and right, rather than 10° and 20°. Finally, data from four adults were collected, using the same procedures as were used with the babies.

A sample of the EOG records obtained is shown in Figure 2, with stimulus onset and offset indicated below and the infant's eye movements above. These records were all scored by a single, trained observer who was blind to the nature and position of the stimulus for each trial. First, the direction of the first eye movement following stimulus onset was noted. Then for trials on which this first movement was directionally

appropriate, its latency from stimulus onset and the number of successive movements also in the appropriate direction and prior to any movement in the opposite direction were recorded. The summed magnitude of the first movement and these successive movements was then computed, using the average total amplitude of his or her 10° visual trials as the standard unit for each infant. So, for example, in the record shown in Figure 2, only the first movement was considered in calculating the magnitude, since the second movement was in the opposite direction. In the record shown in Figure 3, there are three movements to the right or correct direction before one to the left occurred, so the amplitudes of all three were added together to get the magnitude variable for this trial.

The results are very straight-forward. We first considered for each subject the probability that the first eye movement following stimulus onset was a hit; that is, was in the direction of the visual or auditory target. The average probabilities for the various groups and stimulus conditions are shown in Figure 4. First notice that adults made directionally appropriate eye movements on virtually 100% of the trials, whether the target was visual or auditory. It is also immediately apparent that our 2-month-old subjects were quite capable of visually localizing visual targets, as we expected they would be. The average infant's first eye movements were directionally appropriate on 90% of the visual trials for the main group ($t = 23.795_{df = 39}$, $p < .005$; this test and those following which are not otherwise described were one-tailed, one-sample t-tests vs. .50) and on 84% of the visual trials for the smaller group of subjects run at the closer distance ($t = 9.501_{df = 9}$, $p < .005$).

When we compared the hit-rates for the different target positions, we noticed that the infants generally localized the targets more reliably when they were to the right, except for the near auditory condition. We assume this side bias is due to some idiosyncracies of our equipment or procedure. A more important stimulus position effect is that visual targets at 40° were less likely to be localized than those at 20° ($t = 2.02_{df = 9}$, $p = .037$ — one-tailed, paired comparison t-test), though visual targets at 10° and 20° were equally (and highly) likely to be localized.

Though it is not so obvious from Figure 4, our subjects were also able to visually localize the auditory targets. The average infant's first eye movements were directionally appropriate on 58% of the auditory trials for the main group ($t = 3.641_{df = 39}$, $p < .005$) and on 54% of the auditory trials for the smaller group run at the closer distance. The first of these figures is significantly greater than 50% when tested with a one-sample t-test; the second is not. However, the probability of a hit occurring by chance is not really 50%—that figure is too stringent, since in addition to an eye movement to the right or left, there is also the possibility that no saccades will occur. In fact, during some trials (more often on auditory trials) our infants did not make any eye movements, and these trials were considered misses in computing each infant's hit-rates. If, rather than to 50%, the observed hit-rates are compared to a figure which takes into account the possibility of no eye movement occurring, then the near group of infants, as well as the far group, significantly localized the auditory targets ($t = 3.675_{df = 9}$, $p < .005$).

It is clearer yet that our infants visually localized the auditory targets when the individual subjects' hit-rates are considered. The distribution of these is shown in Figure 5. Note first that all of the infants had hit-rates well above 50% for the visual trials. But also note that while some infants had hit-rates below 50% for the auditory trials, a significant proportion of individual babies had hit-rates above 50% for these trials ($w = -2.1974$, $p < .015$ — one-tailed sign test). Figure 5 also illustrates a third point concerning the probability of a directionally appropriate saccade to our stimuli, and that is that although the infants were able to visually localize both visual and auditory targets as I've discussed, they were clearly more consistent in localizing visual targets than in localizing auditory ones (far group—$t = 13.14_{df = 39}$, $p < .001$; near group—$t = 5.88_{df = 9}$, $p < .001$; these tests and all those following were one-tailed, paired comparison t-tests). All but one of the 50 infants we ran in this study had higher hit-rates on their visual trials than on their auditory trials, and the average difference between these two hit-rates was some 30 percentage points.

There were other differences between the localization responses to visual and auditory targets, too. The average latencies of the directionally appropriate first saccades for the various groups and conditions are presented in Figure 6. The latencies on visual trials were shorter than those on auditory trials (10° trials—$t = 4.71_{df = 36}$, $p < .001$; 20° trials—$t = 1.95_{df = 37}$, $p < .03$) and less variable. For visual trials, latencies were shorter for targets 10° to the periphery than for targets 20° to the periphery ($t = 5.57_{df = 38}$, $p < .001$), but for

auditory trials, latency was unrelated to target distance off midline. Adult latencies were of course extremely short for all trials, though perhaps slightly longer for auditory trials.

The average summed magnitudes of successive eye movements on hit trials are presented in Figure 7. As with probability and latency, for visual trials these magnitudes were related to the eccentricity of the stimuli. For each group of infants, the average summed magnitude of eye movements toward the most peripheral targets (at 20° and 40°) was some 40% greater than that of eye movements toward the nearer targets (at 10° and 20°) (far group—$t = 10.57_{df = 38}$, $p < .001$; near group—$t = 3.87_{df = 9}$, $p = .002$). For auditory targets, the magnitudes of directionally appropriate eye movements were more variable, they were not related to target position, and they were generally equivalent to the magnitude of eye movements to visual targets at 10°. For adults, in contrast, the summed magnitudes were related to target eccentricity for visual and for auditory trials.

The average numbers of successive movements in the appropriate direction for the different conditions are presented in Figure 8. As with the other variables, number of successive appropriate movements is related to target position for visual trials but not for auditory trials. Infants made more movements in the direction of a visual target when the target was at 20° and 40° than when it was at 10° ($t = 6.05_{df = 38}$, $p < .001$). They also generally made more successive appropriate movements when localizing a visual target than when localizing an auditory target. Adults usually made only a single eye movement when localizing a target, and the few multiple saccades they did make were mostly toward the most peripheral auditory targets.

To summarize our findings then, 2-month-old infants presented with peripheral visual stimuli were highly likely to make series of saccades in the direction of the targets, and the latency of the first movement in a series as well as the summed magnitude and the number of eye movements in the series were related to how far to the periphery the target was located. When presented with peripheral auditory stimuli, the infants were likely to turn their eyes toward the targets, but not highly likely to do so. When the infants did localize auditory stimuli, their eye movements were of relatively long latency and were similar in magnitude to movements toward visual targets at 10°, no matter how far to the periphery the auditory targets were located.

We conclude from these findings that 2-month-old infants are able to visually localize both visual and auditory stimuli. However, these two localization responses are quite different from one another, at least with the two presumably strong stimuli we used. Infants turn their eyes toward peripheral visual stimuli with the consistency and precision characteristic of reflex behavior. They turn their eyes toward peripheral auditory stimuli with considerably less consistency and with no precision at all; the features of this response are more characteristic of voluntary behavior in the process of being acquired. Although differential acuity or delayed maturation of auditory vs. visual pathways might partially explain the effects I've described, it is also quite possible that the visual localization of sounds by humans may be largely a learned behavior, reflecting the recurrent spatial contiguity of visual and auditory events in the environment. We do not find it too surprising that infants as young as 2 months of age are somewhat sensitive to this environmental contingency, given the countless opportunities to notice it which occur during each day and given the demonstrated memory capacities of such infants.

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Wertheimer, M. Psychomotor coordination of auditory and visual space at birth. Science, 1961, 134, 1692.

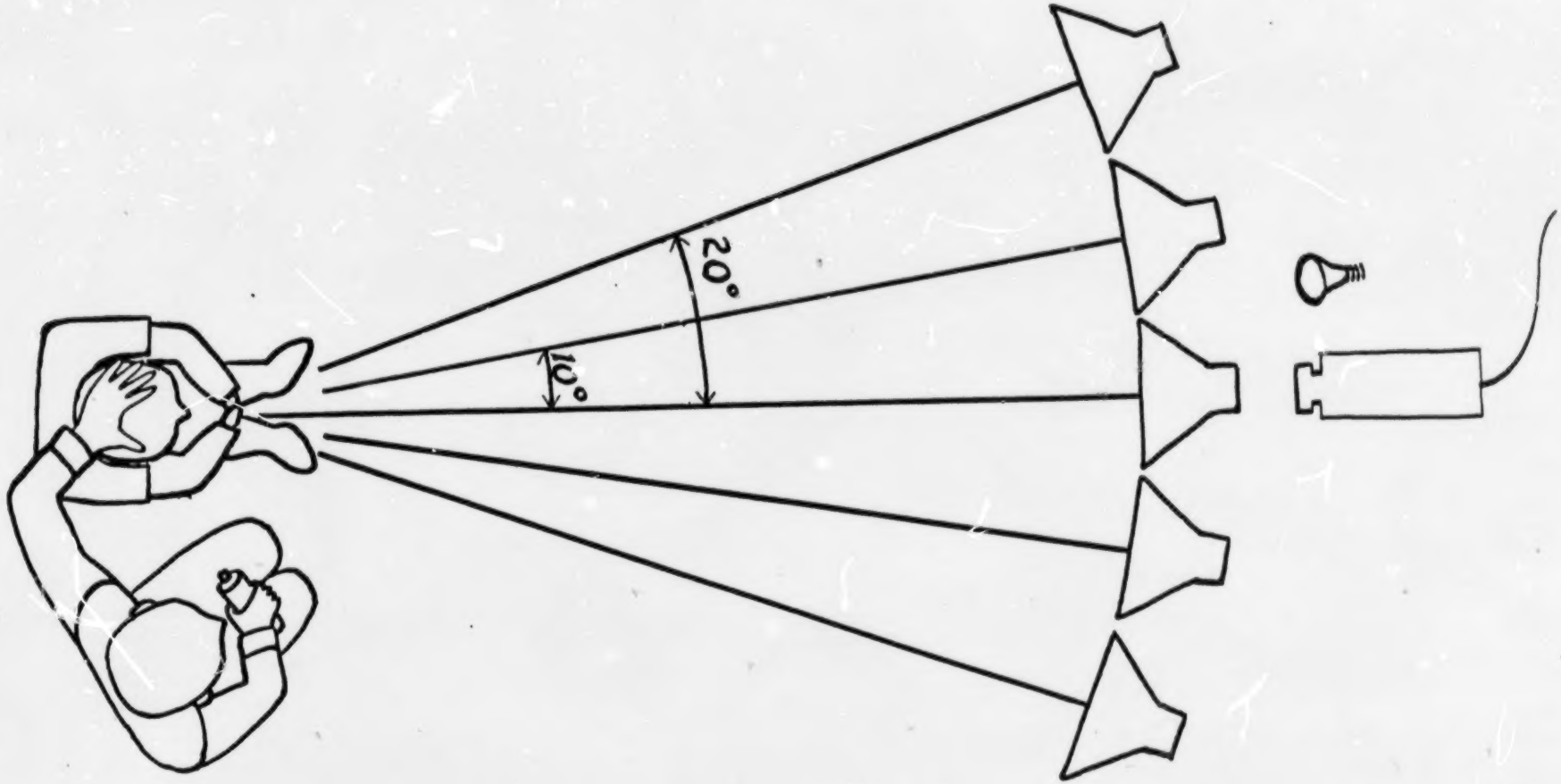
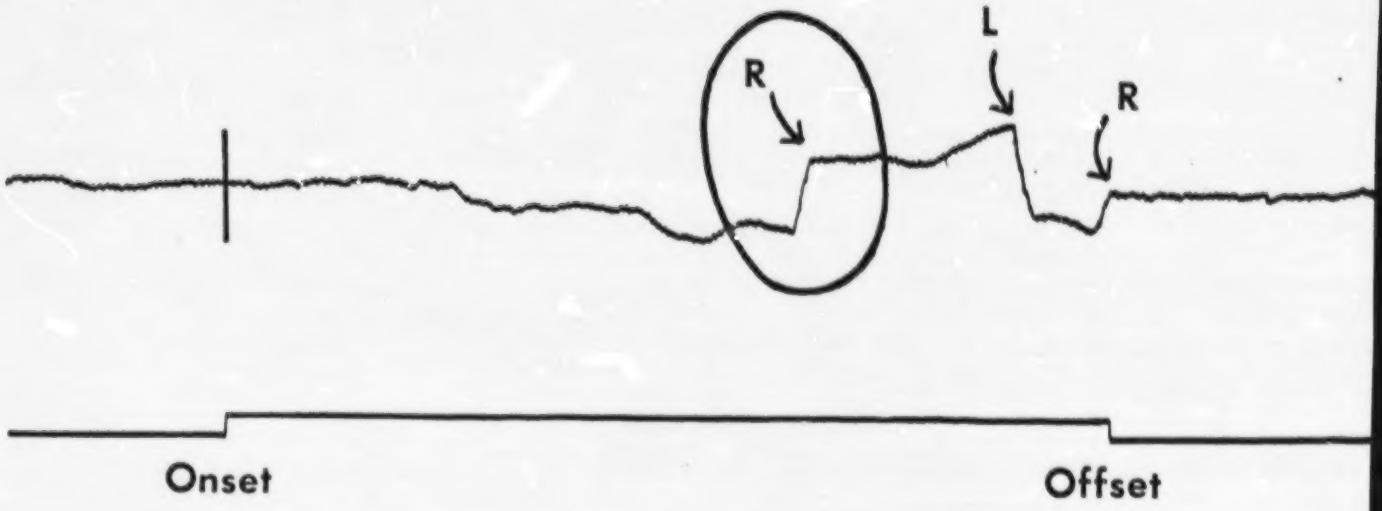


Figure 1. Schematic of experimental chamber.



Auditory : 20° Right

Figure 2. Sample EOG record (A).

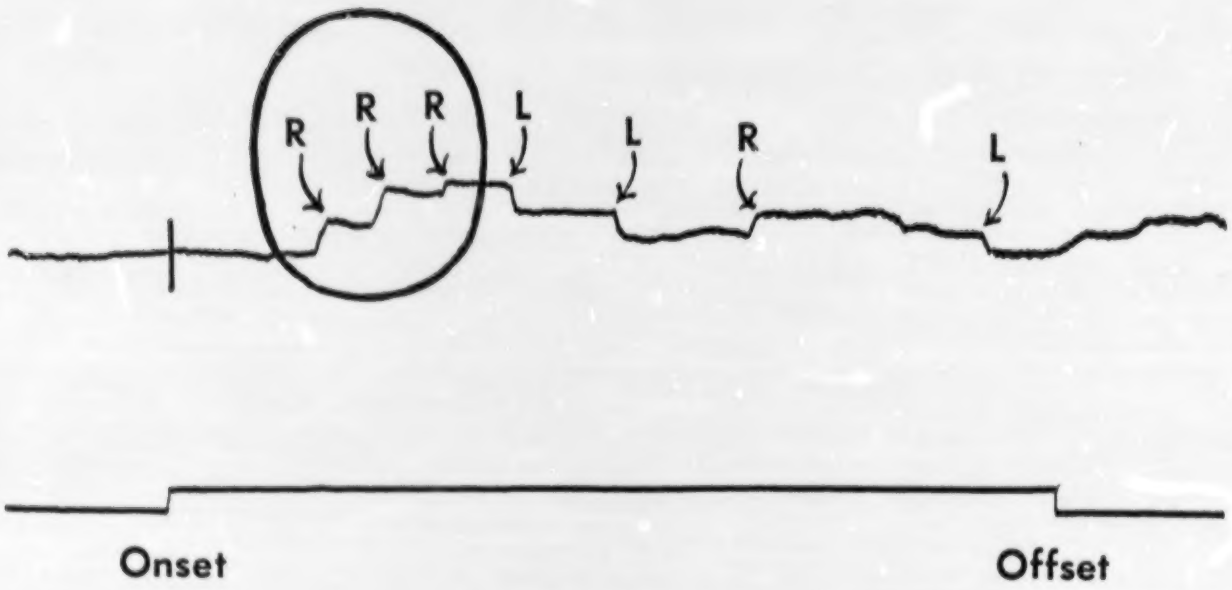
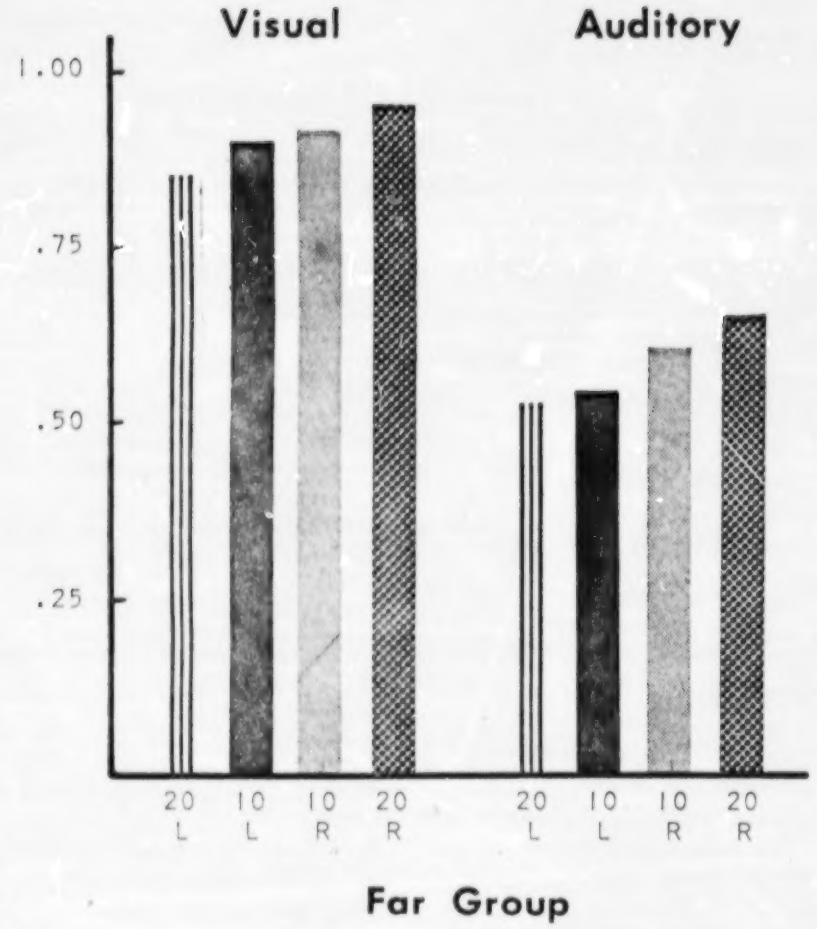
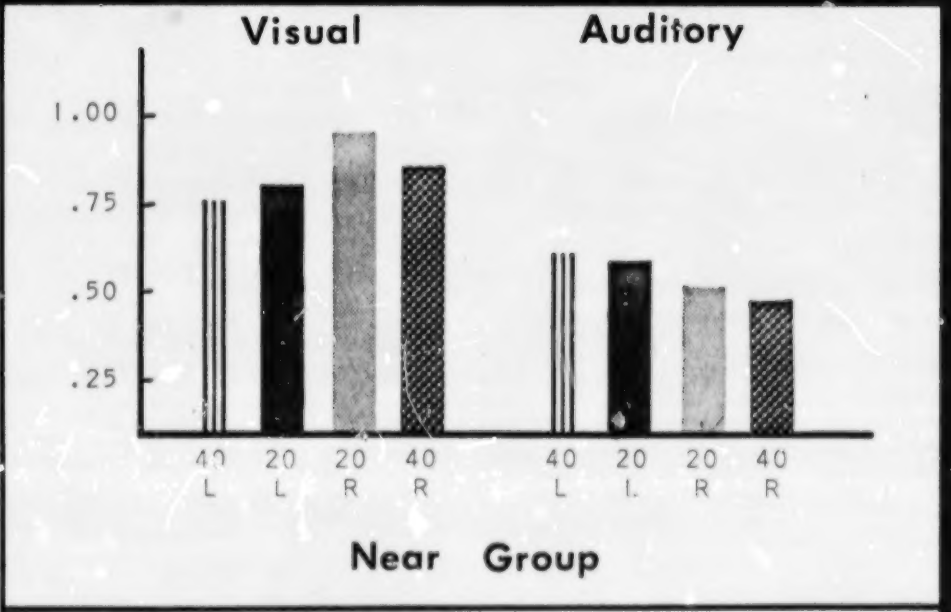


Figure 3. Sample EOG record (B).





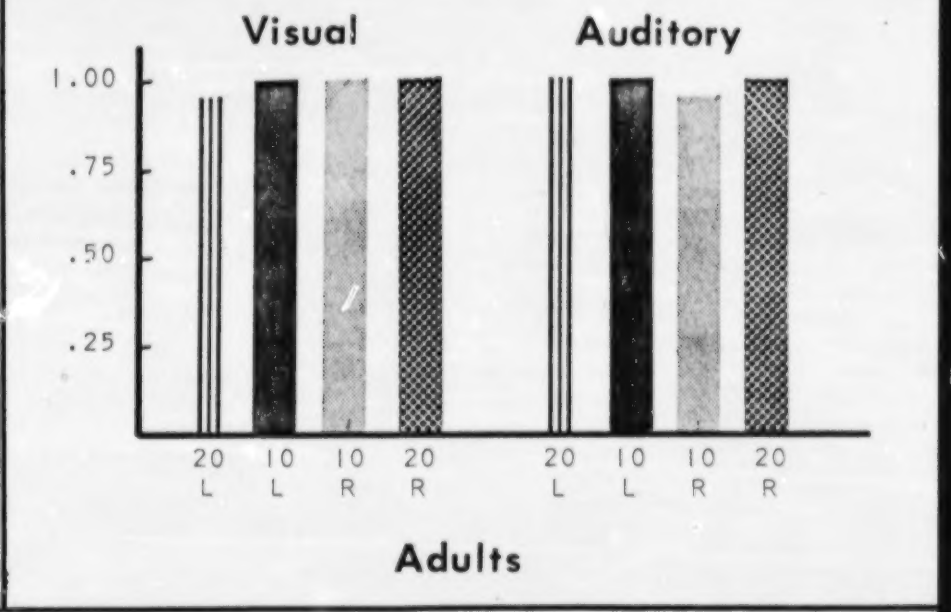
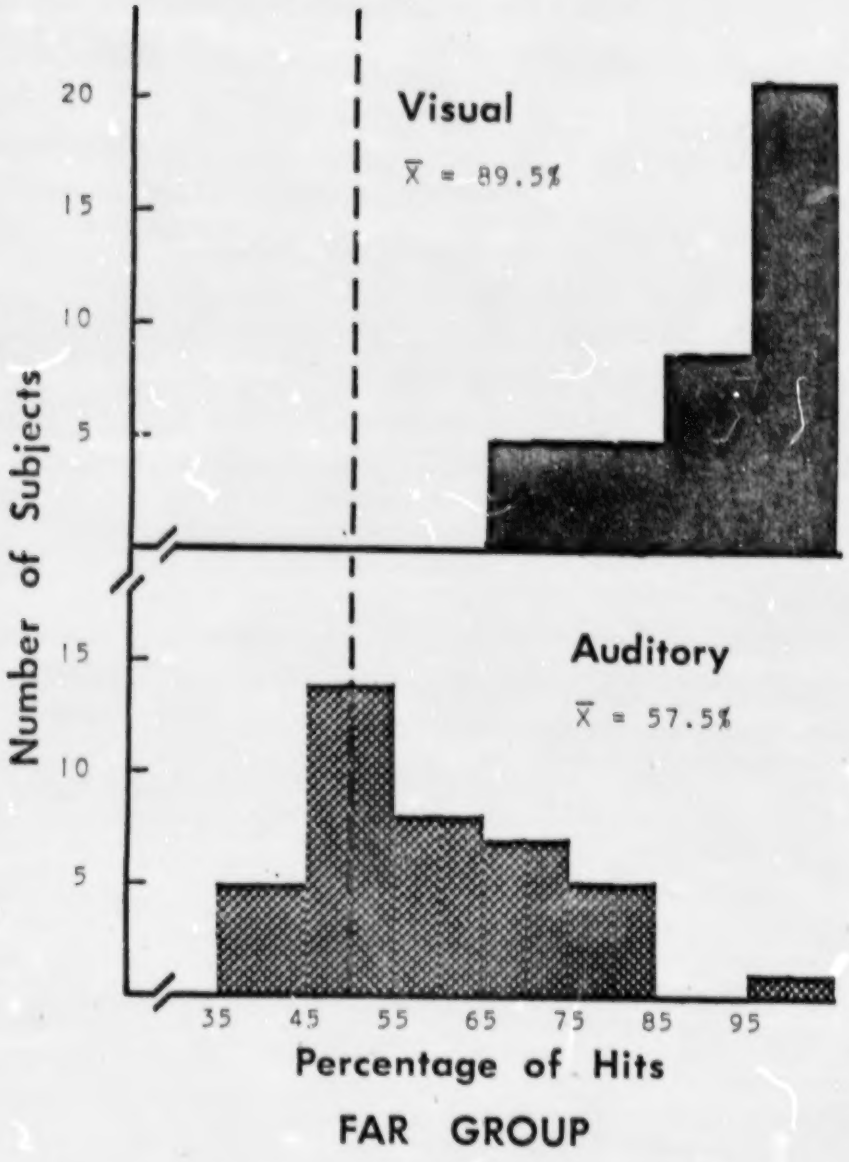


Figure 4. Probability of Directionally Appropriate First Saccade



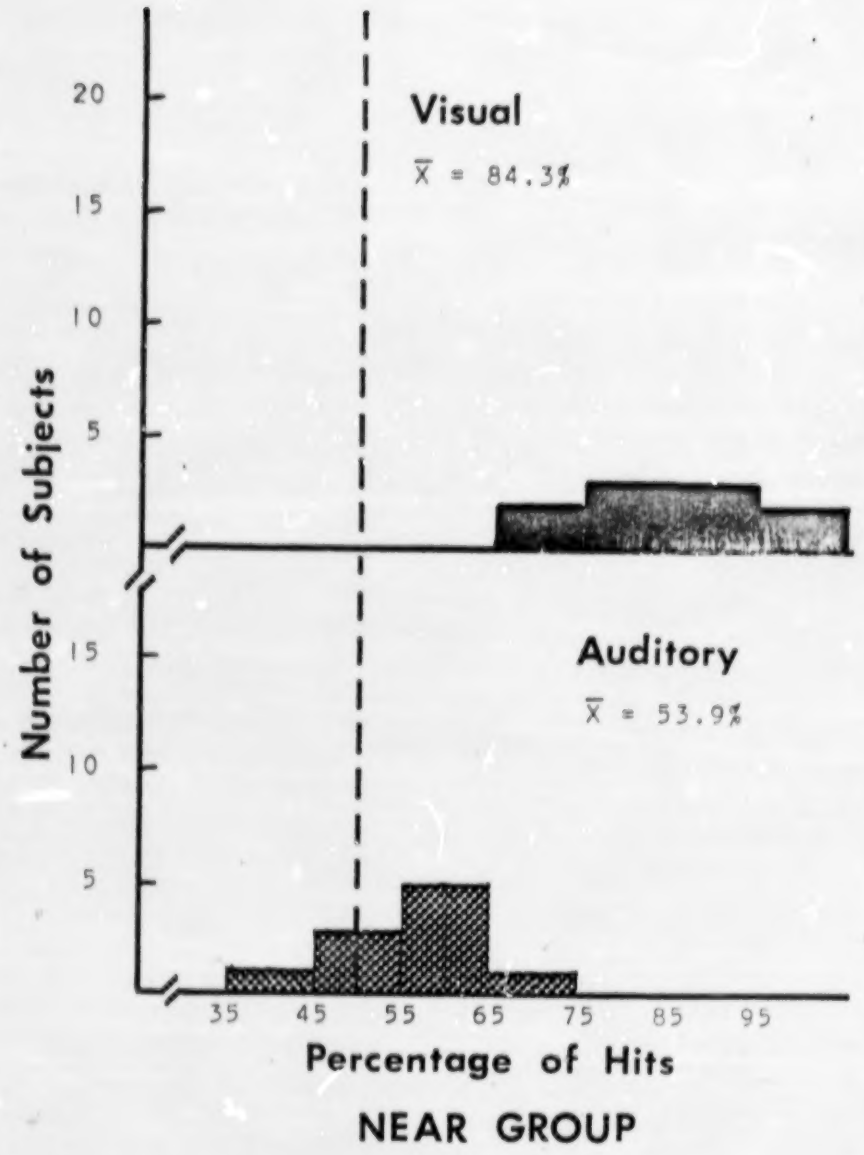
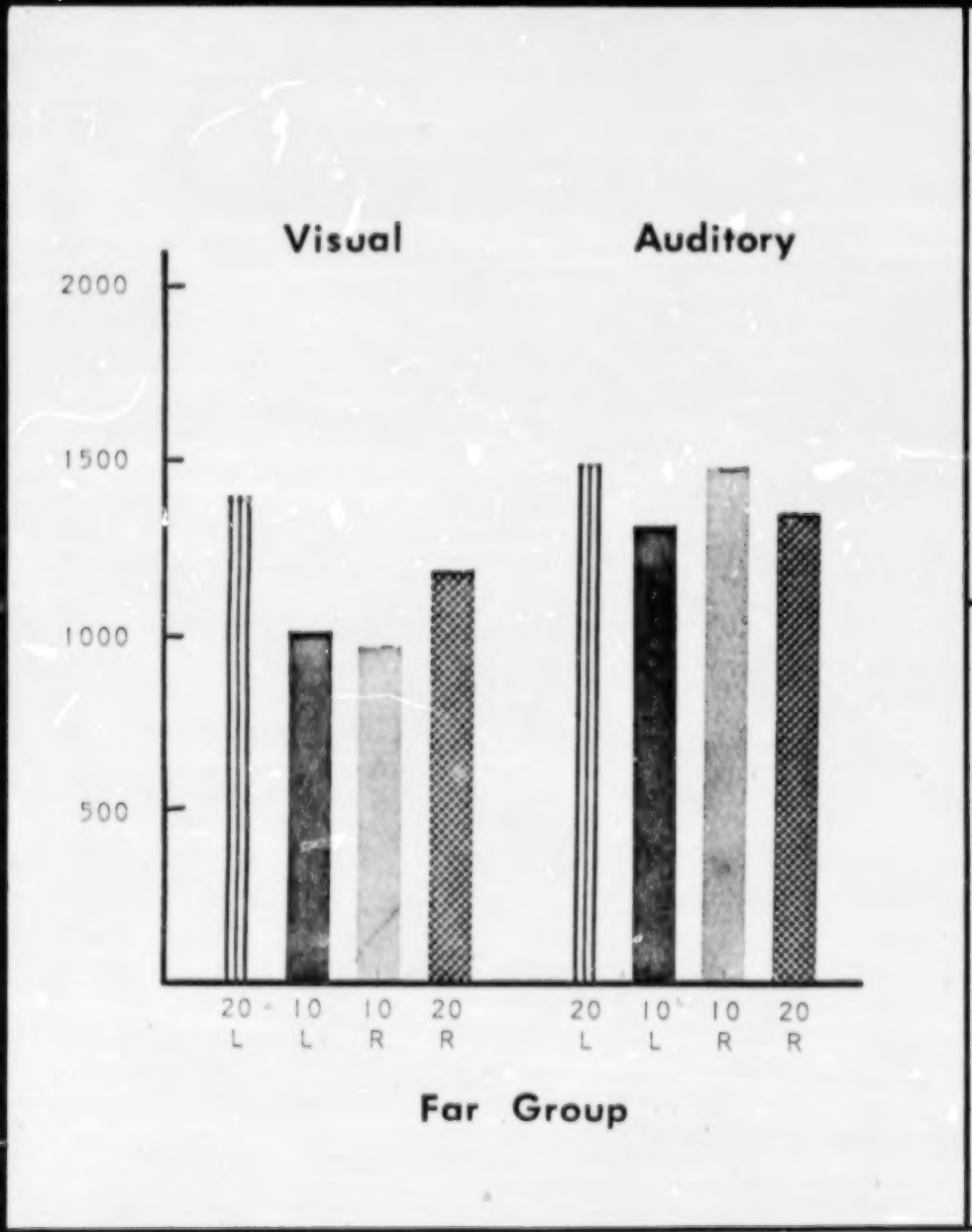
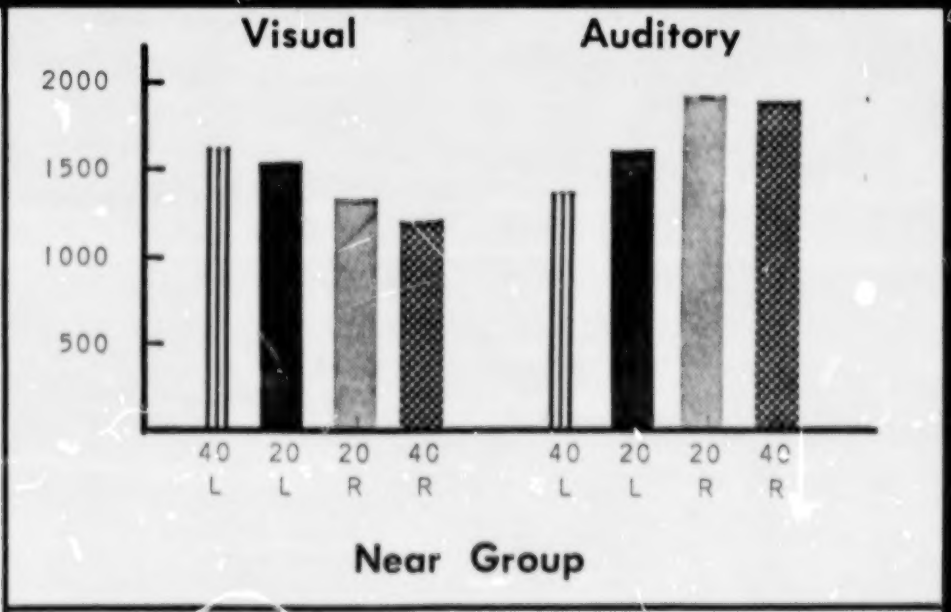


Figure 5. Distribution of Individual Subjects' Hit-Rates





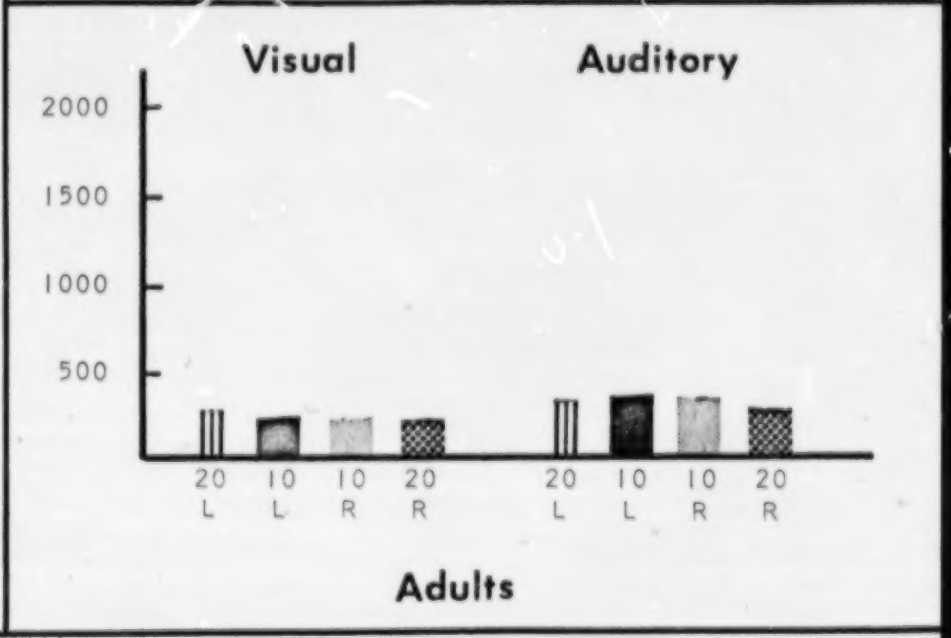
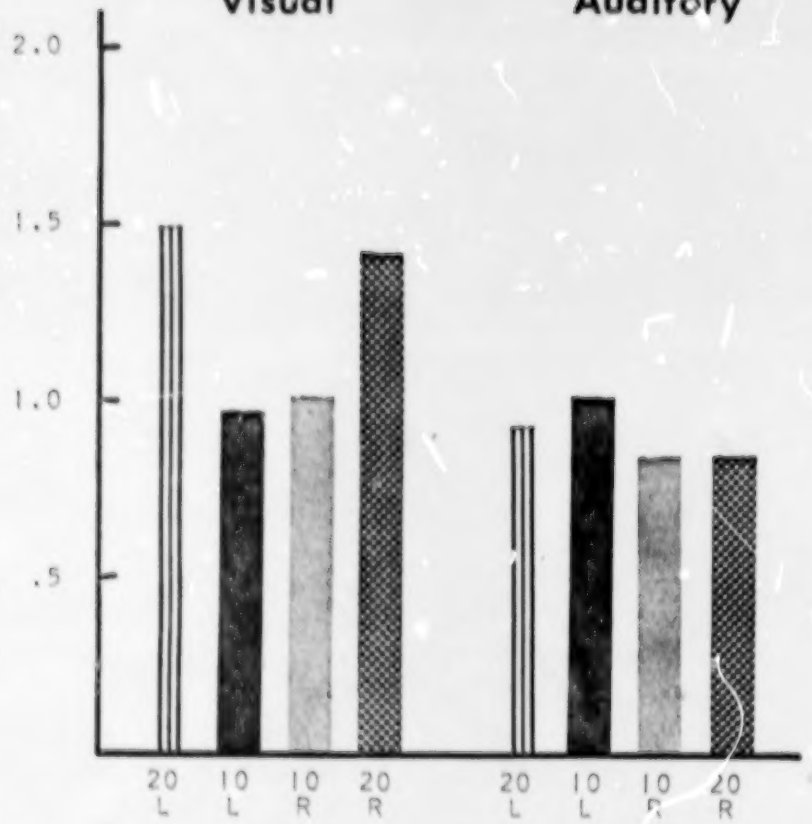
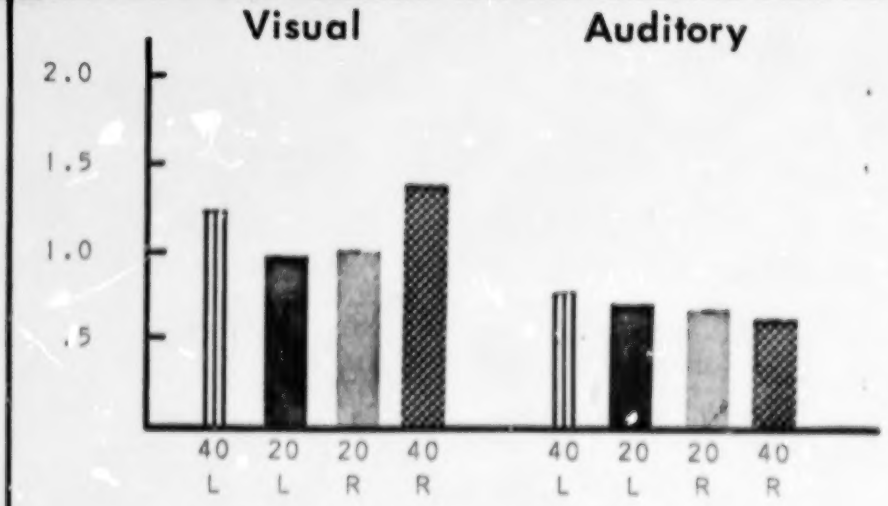


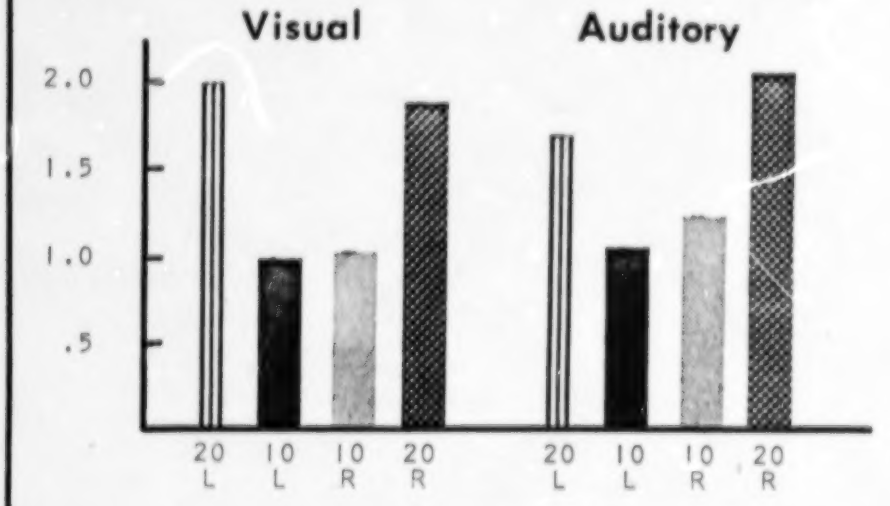
Figure 6. Latency of Directionally Appropriate First Saccade
[In milleseconds]



Far Group



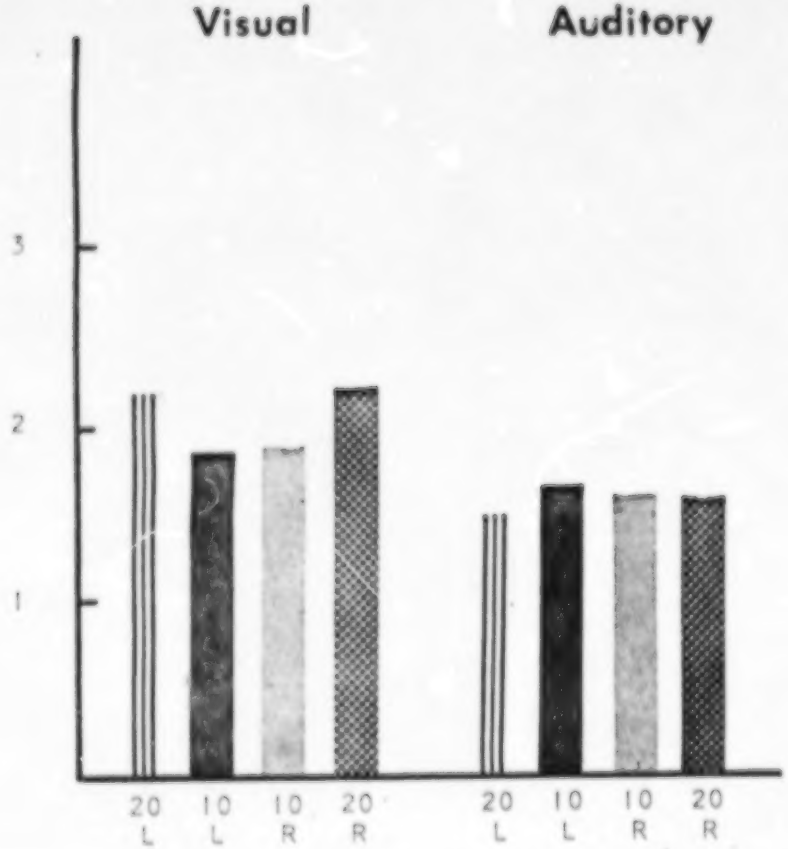
Near Group



Adults

Fig. 7. Magnitude of Directionally Appropriate Eye Movements

[Units = 10° visual trial average for each subject]



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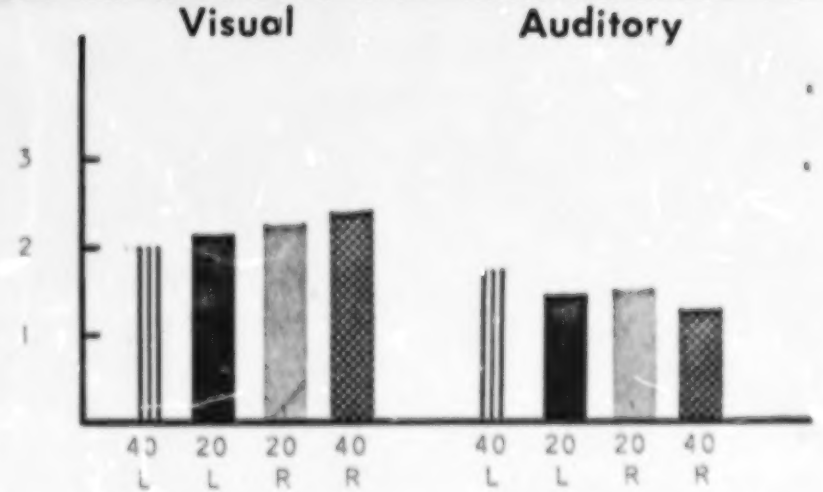

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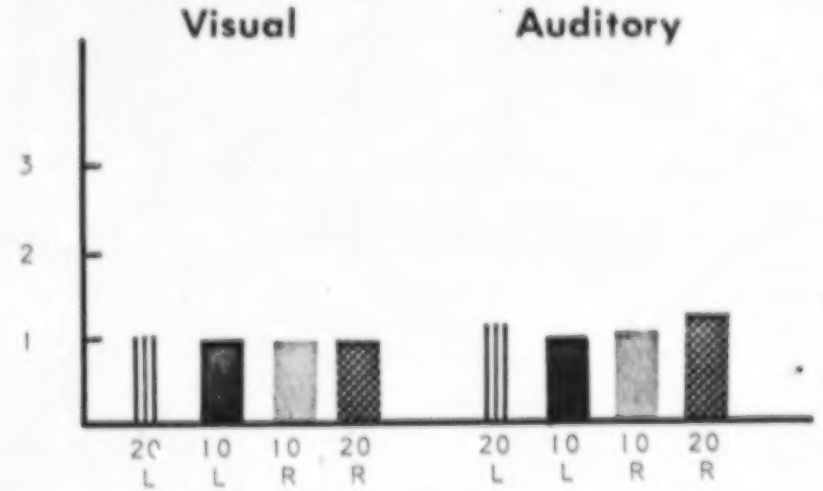

Adults

Figure 8. Number of Movements Before Reversal